Controller Toilet Paper Dispenser

Group SD0607

Final Report

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Background

The automatic toilet paper dispenser allows persons with disabilities to use restrooms without using excessive amounts of toilet paper. A person can wave his or her hand in front of the sensor, and the device unrolls a set amount of toilet paper. This process can be repeated a preset number of times, after which, no additional toilet paper is dispensed until the stall is vacated.

Our client has problems with toilet paper overuse causing clogging of toilets, which led to overflow and involved expensive cleanup. This problem is unique because previously, no effective solutions existed. One possible method to prevent toilet paper overuse is supervision; however, privacy concerns prevent effective monitoring of use in restrooms. While automatic paper towel dispensers exist, no known automatic toilet paper dispensers are commercially available.

Requirements

- The device shall control the amount of toilet paper dispensed per visit to the bathroom.
- Pushing a button or waving a hand in front of a sensor shall trigger dispensing.
- The amount of toilet paper dispensed is to be controlled with a switch on the stall door, allowing another set amount of toilet paper to be dispensed after the door has been opened and shut again.
- The device shall not allow dispensing unless the stall door is closed.
- The device shall have a durable cover with a lock to prevent removal of the roll but allow refilling the roll.
- The device is to be rugged enough to handle many uses throughout each day.
- The cost of the unit should be sufficiently low so as to allow three units to be built.

Design Description

The system has ten main components. The device is battery powered to provide safer operation and allow installation in areas that do not have access to standard wall outlets. Since the device is powered by batteries, power consumption is a concern. To prevent unnecessary power consumption, the device is powered only when the stall is in use. To accomplish this, a magnetic reed switch and bar magnet are mounted to the stall door. When the door is open, the switch is open, breaking the circuit and cutting off power to all of the electronics. When the door is closed, the proximity of the bar magnet to the reed switch closes the circuit and powers the electronics. Since the electronic components and the motor require five volts to operate correctly, a voltage regulator is used to drop the input voltage from the batteries down to five volts. A low dropout voltage regulator was chosen to increase battery life by allowing the batteries to be used further into their charge cycle than a typical voltage regulator would allow. The estimated battery life is over 300 days for six D cell batteries.

The dispenser uses a capacitive transducer to detect when the user wants more toilet paper. A capacitive transducer was chosen because it allows non-contact detection, which provides a more sanitary method of activation. To increase the sensing range, a metal sheet mounted to the side of the enclosure is used as a sensing electrode. The size of the electrode can be adjusted to increase or decrease the sensing range. Currently, a hand within three to four inches of the electrode will trigger a sense. Starting the motor could cause momentary changes in the output voltage of the voltage regulator that could cause false touches to be recorded by the sensor. To prevent this, the capacitive transducer runs off its own voltage regulator.

A microcontroller detects touches from the capacitive transducer and controls the stepping pattern used to drive the motor. This eliminates the need for a costly control board to manage the stepper motor. An internal counter is maintained to track the number of dispenses left. Once this counter reaches zero, the controller will no longer respond to touches signaled from the sensor. The microcontroller interfaces with an array of light emitting diodes (LED) indicating the number of dispenses left. The array also features an LED controlled by the voltage regulator that indicates when the batteries need to be replaced.

A stepper motor was chosen to drive the roller because it allows precise control of the amount of toilet paper to be dispensed and is easily controlled through a microcontroller. The toilet paper is unrolled by a pinch roller mechanism. Figure three details the operation of the pinch roller. The roller squeezes the toilet paper between two rubber rollers, the capstan and the idler. The capstan is driven by a motor and the idler is allowed to turn freely. As the capstan is turned, the roll of toilet paper turns and gravity feeds the sheets through a chute and out of the enclosure. The pinch roller is superior to turning the entire roll, because the amount dispensed per revolution stays constant as the roll is used and the diameter of the roll decreases.

The overall estimated cost of a single unit is $153.69. Significant cost reductions could be achieved if the unit were brought into full-scale production. For more information and a detailed design document please refer to the NDSU Electrical and Computer Engineering Senior Design Group SD0607 website.

Block Diagrams

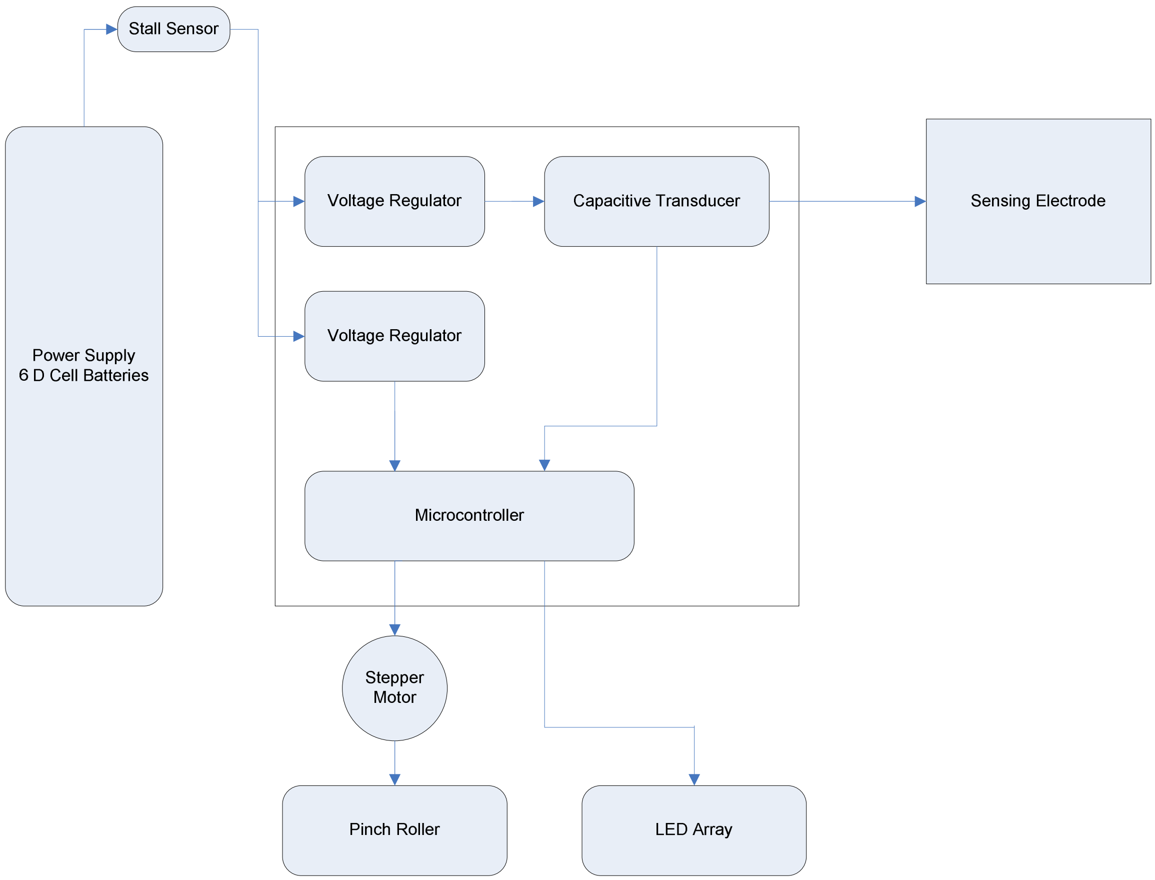


Figure 1: Toilet paper dispenser block diagram

PCB Information and Schematics

Header Connections

Each header pin of our schematics are given any one of the following labels:
Main Header and LED Header Pins:

- **Sensing_Electrode:** refers to the wire connected to the sensing electrode
- **GND_In:** refers to the common ground coming from the battery source
- **Sens_PWR:** refers to the anode of the "touch indicator LED"
- **Sens_GND:** refers to the cathode of the "touch indicator LED"
- **GND_Out:** refers to the common ground going out to the "LED PCB"
- **Batt:** refers to the anode of the "low battery indicator LED"
- **PWR:** refers to the 9 volts of power coming in from the battery source

PORTB Pins 1-6: refer to the first six pins of PORTB as seen on the PIC
MOTOR Pins 1-6: refer to the six wires connected to our stepper motor

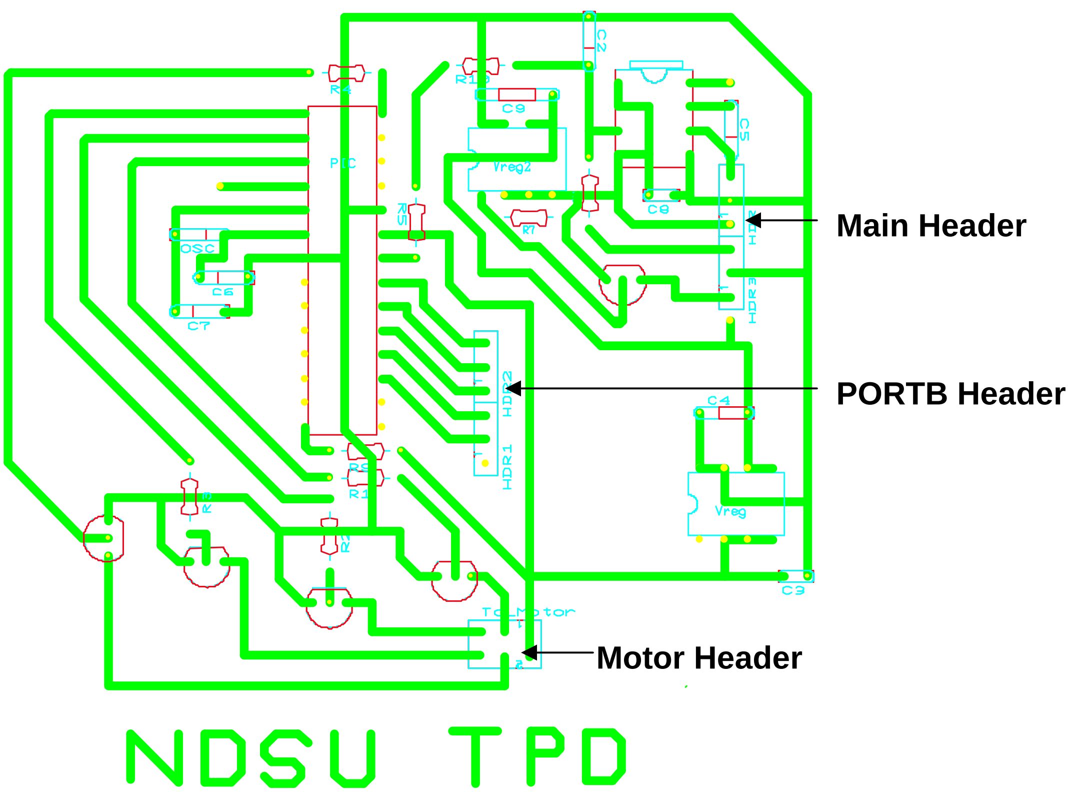


Figure 2: Main PCB Layout

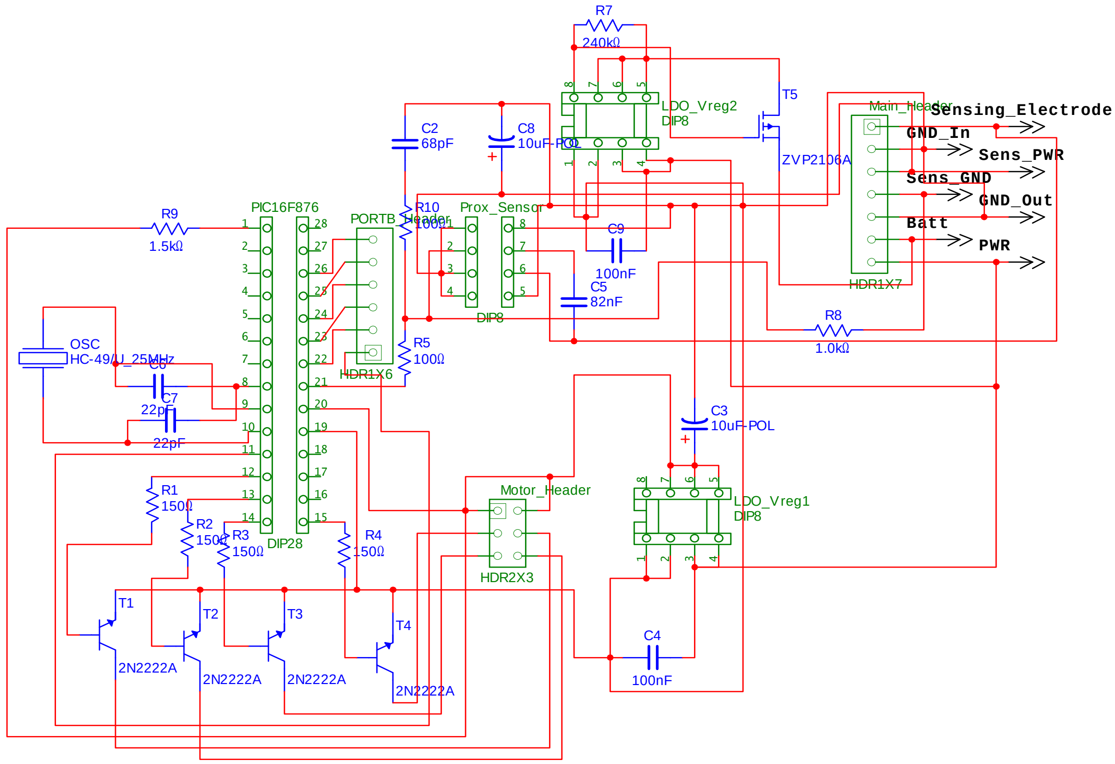


Figure 3: Main PCB Schematic

LEDs

The numbers 1 through 8 in the following below are given the following names:

1. Dispenses Left Indicator #1 – red clear LED
2. Dispenses Left Indicator #2 – red clear LED
3. Dispenses Left Indicator #3 – red clear LED
4. Dispenses Left Indicator #4 – red clear LED
5. Dispenses Left Indicator #5 – red clear LED
6. Touch Indicator – green clear LED
7. Dispensing Indicator – green clear LED
8. Low Battery Indicator – red clear LED

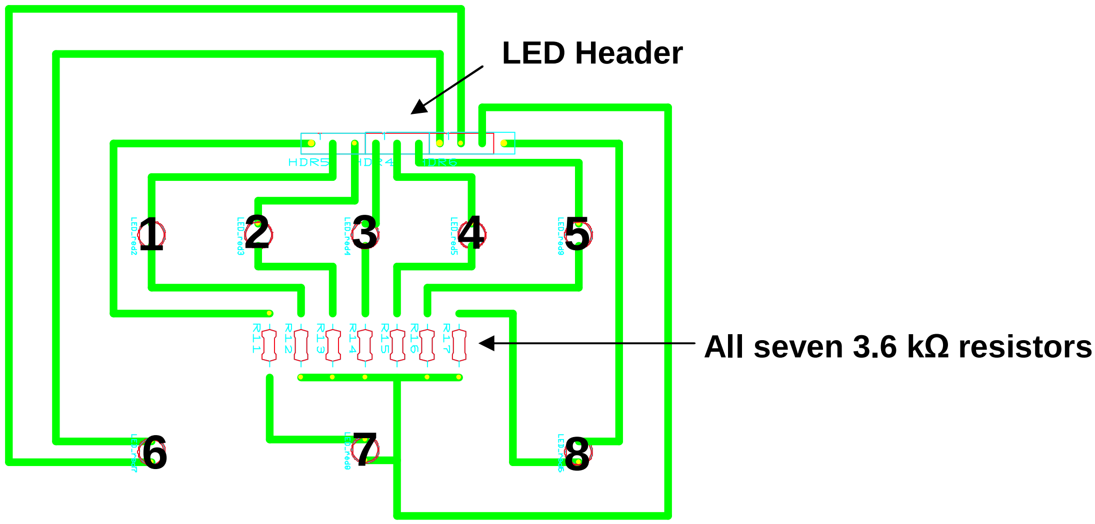


Figure 4: LED PCB Layout

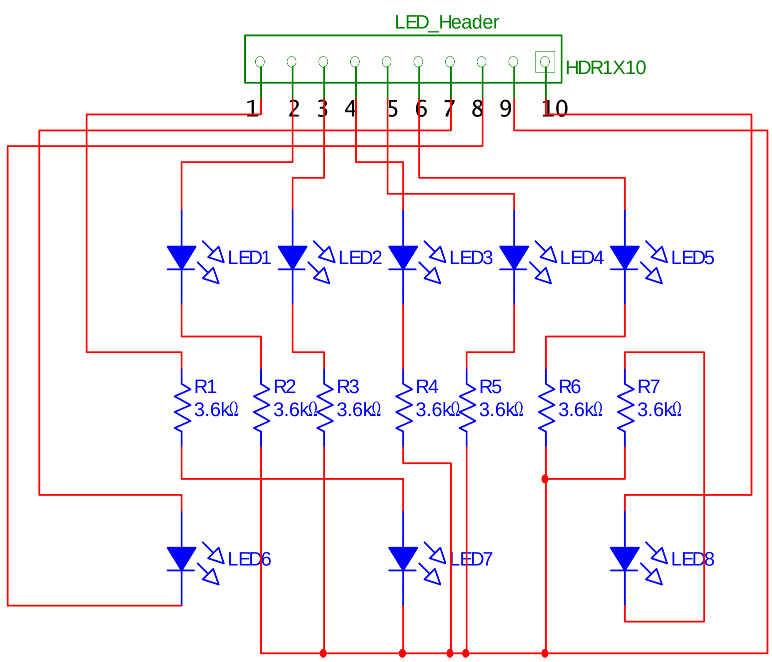


Figure 5: LED PCB Schematic

Header Pins:
1. PORTB Pin 6
2. PORTB Pin 1
3. PORTB Pin 2
4. PORTB Pin 3
5. PORTB Pin 4
6. PORTB Pin 5
7. Sens_PWR
8. Sens_GND
9. GND_Out
10. Batt

Header Wiring

Each header connection is designated with the following wire colors:
(note: some wire colors were used for more than one wire)

Sensing_Electrode: yellow
GND_In: black
Sens_PWR: green
Sens_GND: yellow
GND_Out: red

Batt: red
PWR: red
PORTB Pins 1-6:

1. white
2. white
3. yellow
4. green
5. red
6. black

Motor Pins 1-6:

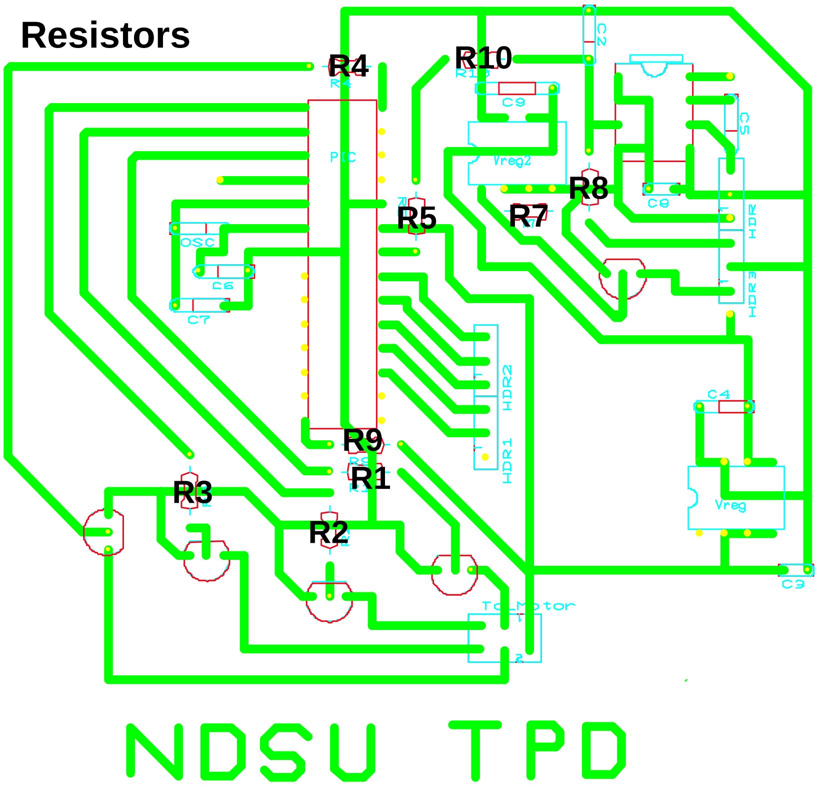
1. green
2. black
3. brown
4. red
5. yellow
6. orange

Components

The two PCB layouts below show the actual values of the resistors and capacitors used on our “Main PCB”:

(note: some components were deleted through the design process)

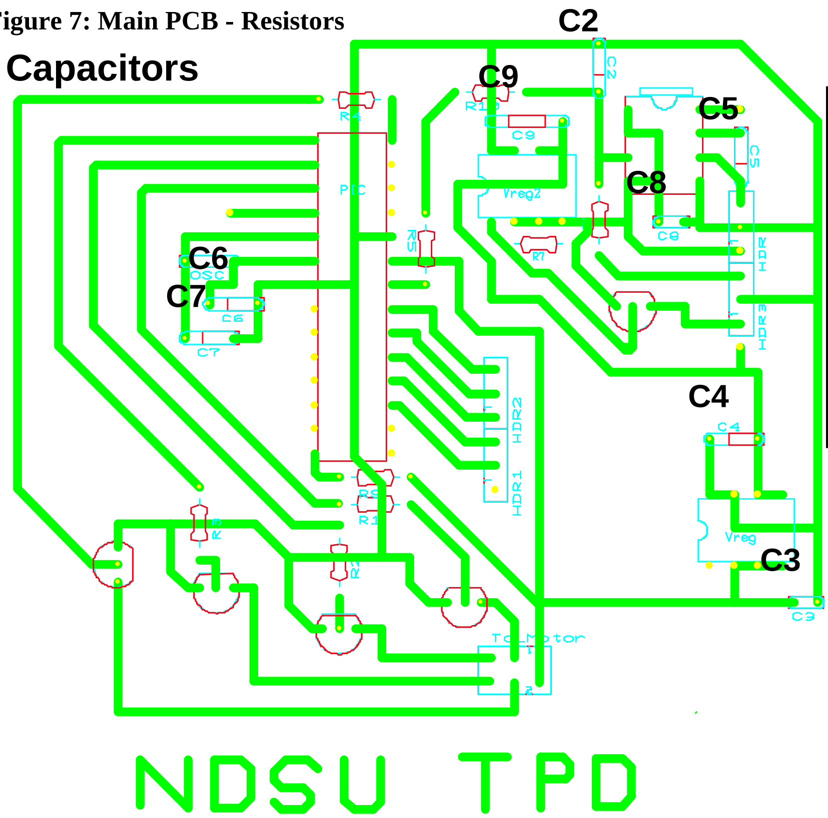
Resistors



- R1: 150 Ω
- R2: 150 Ω
- R3: 150 Ω
- R4: 150 Ω
- R5: 100 Ω
- R6: (deleted)
- R7: 240 kΩ
- R8: 1 kΩ
- R9: 1.5 kΩ
- R10: 100 Ω

Figure 7: Main PCB - Resistors

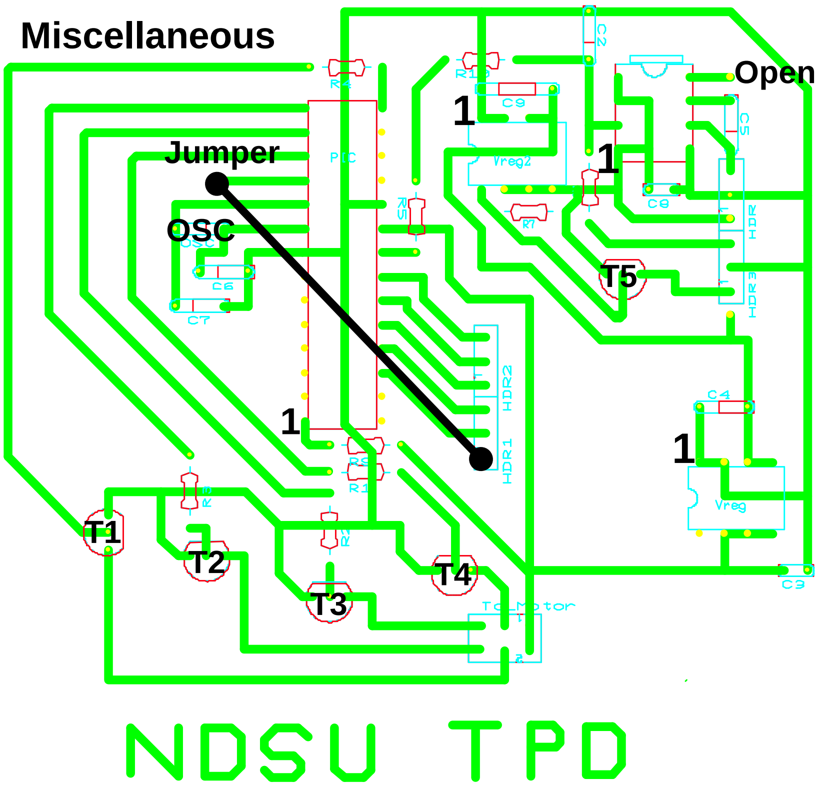
Capacitors



- C1: (deleted)
- C2: 68 pF
- C3: 10 μF-POL
- C4: 100 nF
- C5: 82 nF
- C6: 22 pF
- C7: 22 pF
- C8: 10 μF-POL
- C9: 100 nF

Figure 6: Main PCB - Capacitors

On the PCB layout below, the Integrated Circuits (ICs) are marked with a "**1**" to indicate the position of pin #1. The ICs used include two voltage regulators, a capacitance transducer, and a PIC. The only other components used include five transistors and an oscillator.



Transistors:
T1 – T4: NPN2222A
T5: ZVP 2110A

OSC: 20 MHz crystal oscillator NYP200-20

Figure 8: Main PCB - Miscellaneous Components

The pin marked "**Open**" is the gain pin of our capacitance transducer. This pin can be tied to 5V to increase the sensitivity of the sensing electrode or tied to ground to decrease it.
The line marked "**Jumper**" indicates that a jumper must be used between these two open pins in order for pin 6 of PORTB to be connected properly.

Flow Charts

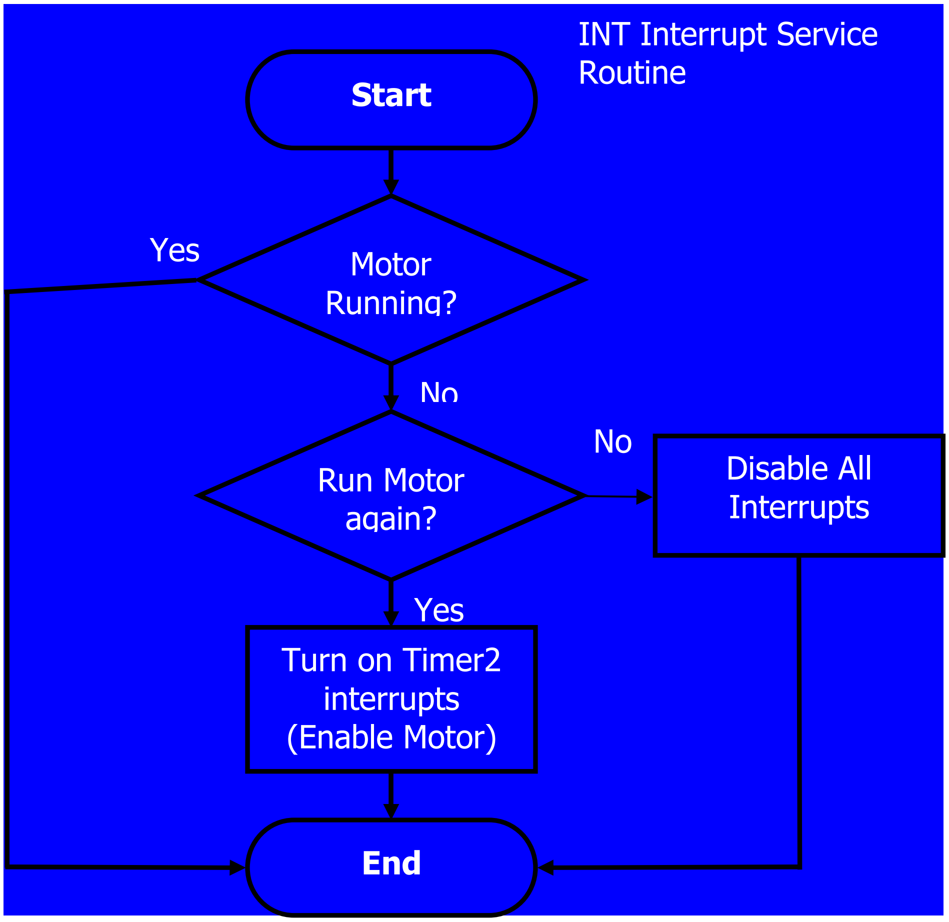


Figure 9: INT Interrupt flow chart

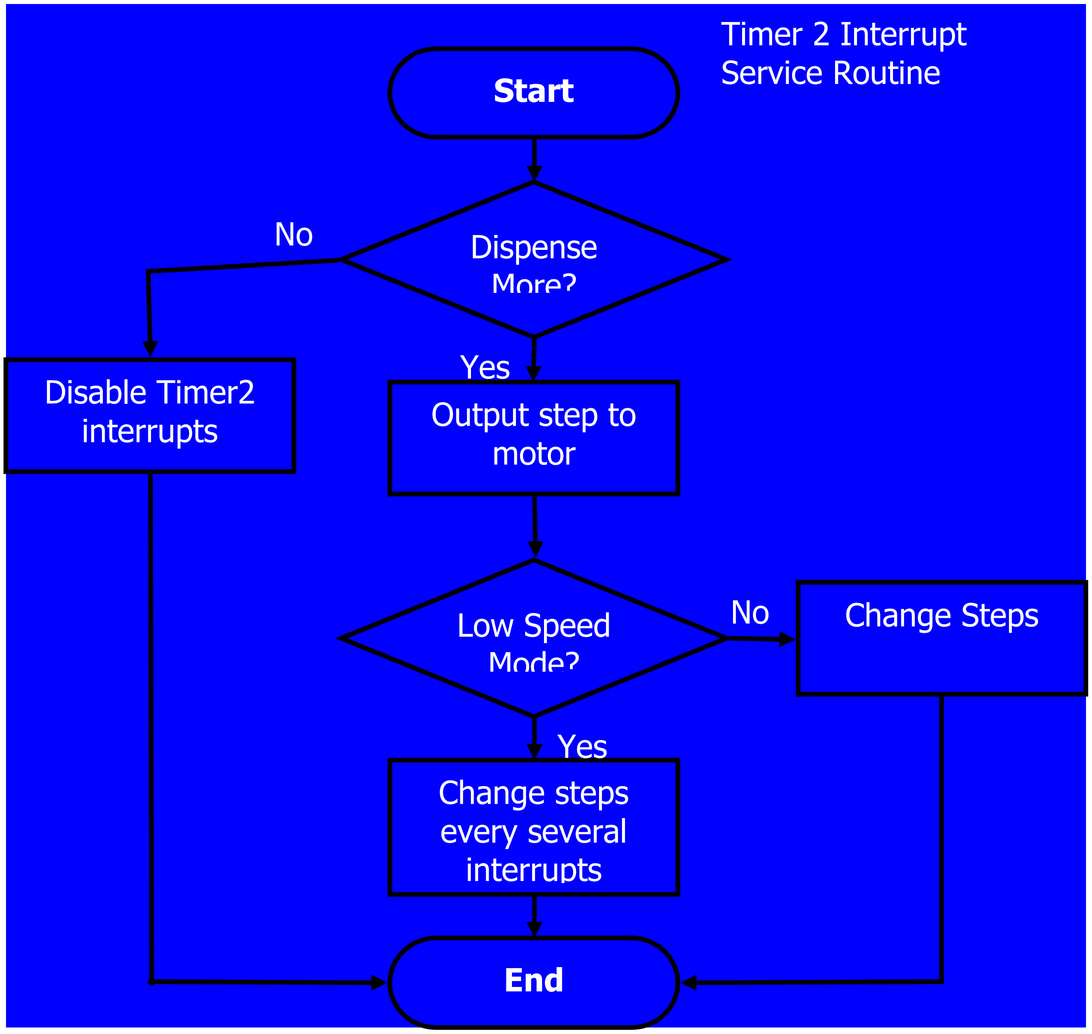


Figure 10: Timer 2 Interrupt flow chart

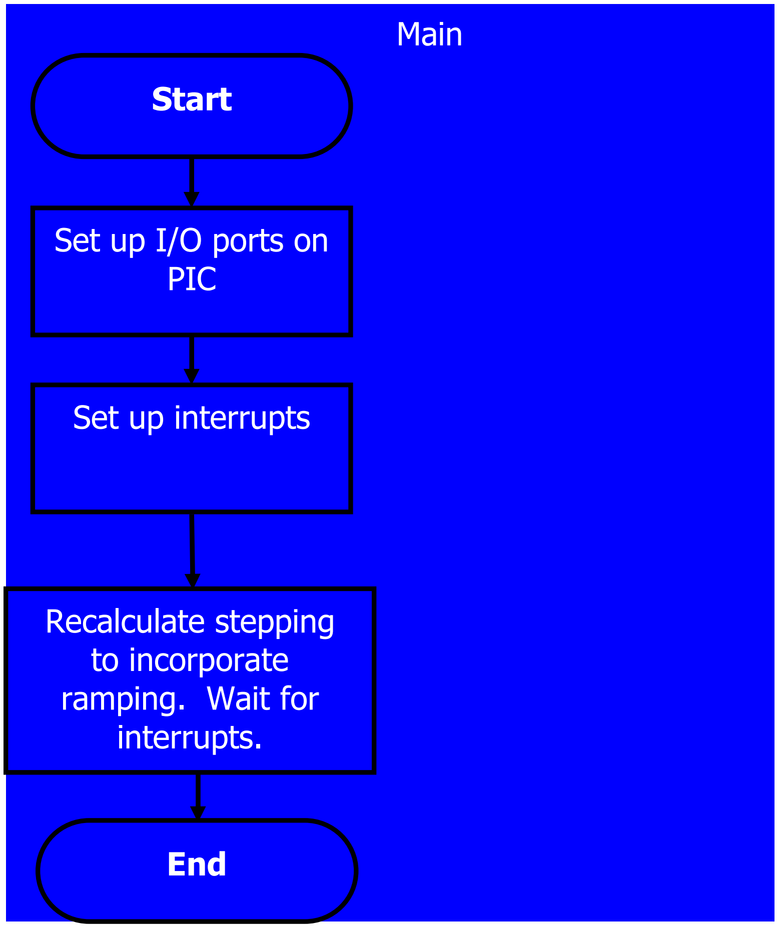


Figure 11: Main method flow chart

Detailed Descriptions

Pinch Roller

A pinch roller was chosen to dispense the toilet paper because the amount of toilet paper per revolution of the roll remains constant. The toilet paper is pinched between to rods, the capstan and the idler. The capstan is coupled to the motor and the idler is allowed to turn freely. As the motor rotates the idler, the toilet paper is pulled down of the roll, and gravity feeds down through the chute and out of the enclosure.

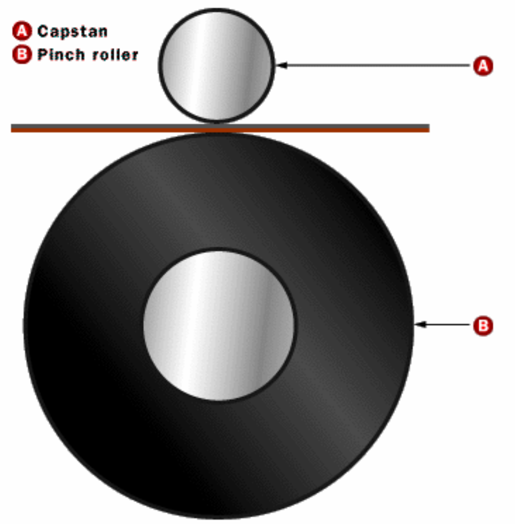
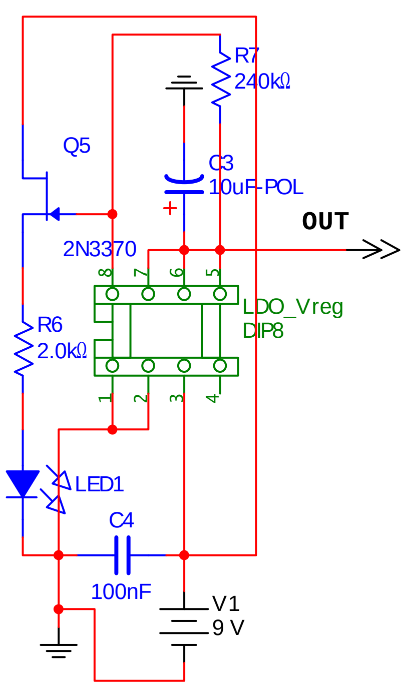


Figure 12: Pinch Roller Design

The pinch roller is constructed from neoprene rubber tubing and a garrolite rod. The inner diameter of the tube and the diameter of the plastic rod were matched, insuring a tight fit when the rod was placed inside the tube. Neoprene rubber was chosen because it is commonly available and provided sufficient sponginess so the paper fed through and did not tear at the roller.

Voltage Regulator



PINS
1 GND
2 EN
3 IN
4 IN
5 OUT
6 OUT
7 SENSE
8 PG

Figure 13: Voltage Regulator Setup

A low-dropout voltage regulator was chosen because the device is battery powered. The 7805, a typical voltage regulator has a dropout voltage of 2.5V, meaning that if the supply voltage drops below 7.5V, the output is not guaranteed to be 5V. The TPS7150QP has a dropout voltage much lower than this, 230V at the maximum current rating. In addition, the voltage regulator chosen has a very low quiescent current, so very little power while the circuit is inactive. The low dropout voltage

and quiescent current allow

use of the batteries much further into their charge cycle, increasing the time between battery changes.

The regulator chosen also features a power good pin that exhibits a logical high signal when the regulator output is within 92-98% of the nominal regulated value. When the output falls below this threshold, the pin exhibits a logical low signal. The output of this pin is connected to the gate of a PFET. When the pin turns off, the transistor turns on, supplying power to the low battery LED.

Capacitance Transducer

The dispenser uses a capacitive transducer to detect when the user wants more toilet paper. A capacitive transducer was chosen because it allows non-contact detection, which provides a more sanitary method of activation. To increase the sensing range, a metal sheet mounted to the side of the enclosure is used as a sensing electrode. The size of the electrode can be adjusted to increase or decrease the sensing range. Currently, a hand within three to four inches of the electrode will trigger a sense. Starting the motor could cause momentary changes in the output voltage of the voltage regulator that could cause false touches to be recorded by the sensor. To prevent this, the capacitive transducer runs off its own voltage regulator.

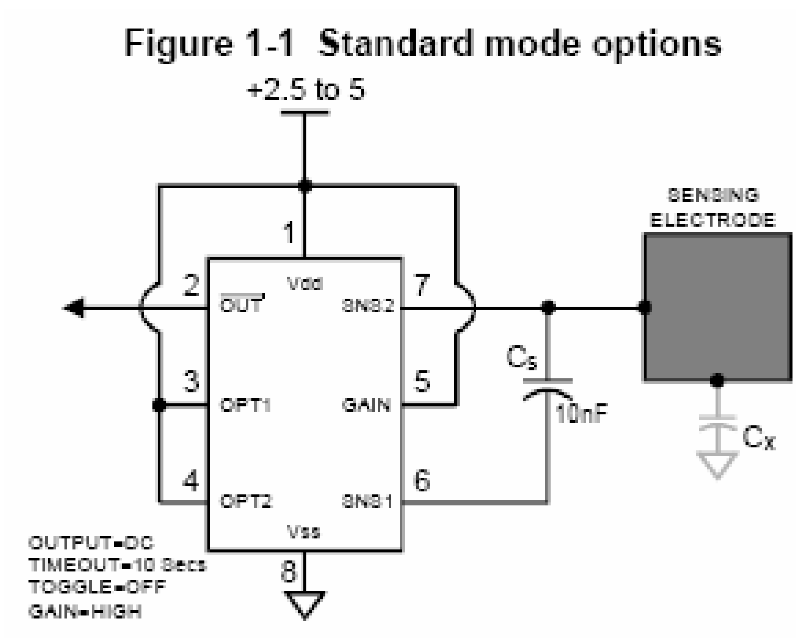


Figure 14: Capacitance Transcuder Setup

Design Implementation methods

When implementing the project, we used divide and conquer methods. Initially, we learned about, designed with and tested individual components. Once we were confident that our voltage regulator was set up correctly, the reed switch was working properly, the PIC code was implemented correctly, and the capacitive transducer was performing as expected, we began small-scale integration testing. This involved testing the PIC with the stepper motor, the electronics with the voltage regulator, the motor with the voltage regulator, and the PIC with the capacitive transducer. These first two phases were especially conducive to us working in parallel on separate projects. Once we were confident all our components were working together correctly, we began full-scale integration. Of course, as we integrated more of our components together, testing was required to ensure everything worked together. Minor redesigns were necessary after we learned more about how our project was performing.

Cost

NDSU Automatic Toilet Paper Dispenser Parts List

Part	Manufacturer	Manufacturer Part Number	Vendor	Vendor Part Number	Unit Cost	# Units	Total Cost	Acquired Cost	Notes
Main Electrical Components									
Reed Switch	Coto Technology	RI-21	Digikey	306-1188-ND	0.78	1	$0.78	$0.78	
Bar Magnet	Hamlin Electronics		Digikey	HE510-ND	1.24	1	$1.24	$1.24	
Voltage Regulator	Texas Instruments	TPS7150QP	Digikey	296-8050-5-ND	2.81	2	$5.62	$5.62	
Capacitive Transducer	Quantum	QT113	Digikey	427-1095- ND	5.08	1	$5.08	$5.08	
Microcontroller	Microchip	PIC165876a	Digikey		7.7	1	$7.70	$7.70	
Stepper Motor				403-1023-ND	17.8	1	$17.80	$17.80	
Printed Circuit Board			Advanced Circuits	-	33	1	$33.00	$0.00	PCB Made in House
Misc. Electrical Components									
Resistor 100 Ω			Digikey	100QBK-ND	0.27	2	$0.54	$0.00	Obtained from Parts Bins
Resistor 150 Ω			Digikey	150QBK-ND	0.27	4	$1.08	$0.00	Obtained from Parts Bins
Resistor 1 kΩ			Digikey	1.0KQBK-ND	0.27	1	$0.27	$0.00	Obtained from Parts Bins
Resistor 1.5 kΩ			Digikey	CFR-25JB-1K5	0.052	1	$0.05	$0.00	Obtained from Parts Bins
Resistor 240 kΩ			Digikey	240KQBK-ND	0.27	1			
Capacitor 22 pF			Digikey	1358PH-ND	0.137	2	$0.27	$0.00	Obtained from Parts Bins
Capacitor 68 pF			Digikey	1018PHCT-ND	0.12	1	$0.12	$0.00	Obtained from Parts Bins
Capacitor 10 uF- Tantalum			Digikey	478-1831-ND		2	$0.00	$0.00	Obtained from Parts Bins
Capacitor 82 nF			Digikey	399-3485-1-ND	0.354	1	$0.35	$0.00	Obtained from Parts

									Bins
Capacitor .1 uF			Digikey	1109PHCT-ND	0.084	2	$0.17	$0.00	Obtained from Parts Bins
PFET Transistor			Digikey	ZVP2110A-ND	1.24	1	$1.24	$0.00	Obtained from Parts Bins
NPN Transitor			Digikey	568-3992-ND	0.12	4	$0.48	$0.00	Obtained from Parts Bins
Mechanical Components									
Enclosure	Standard Industries	-	-	-	50	1	$50.00	$50.00	
Battery Holder	Eagle Plastic Devices	12BH163-GR	Mouser	12BH163-GR	2.79	1	$2.79	$2.79	
Garrolite Rod 1/4" Diameter			McMaster-Carr	8526K11	0.25	1.1	$0.28	$0.28	
Rubber Tubing 1/4" Inside Diameter			McMaster-Carr	8637K51	0.33	7.8	$2.57	$2.57	
Helical Beam Coupling 1/4" - 3mm			McMaster-Carr	6208k999	$22.25	1	$22.25	$22.25	
							Theoretical	**Acquired**	
						Total	153.69	116.11	

Figure 15: Parts list for an automatic toilet paper dispenser

Software

The PIC software used to control the Automatic Toilet Paper Dispenser consists primarily of interrupt service routines. The program that runs on the PIC is called StepperWInt, and it is included on the CD, as well as in the appendix of this document. Please note that flow diagrams for the main method as well as interrupts are included in the Flow Chart section of this document. In the main method, the interrupts are initialized, and some basic computations are done to generate values for speed stepping the motor, if necessary. Additionally, LEDs are turned on to indicate the number of dispenses left. At this point, the PIC waits for interrupts to occur.

INT interrupts are used to detect when the capacitive transducer senses a change in capacitance. In the INT routine, if there are dispenses left, Timer2 interrupts are turned on. If there are no dispenses left, the INT routine disables interrupts.

In the Timer2 interrupt service routine, the motor is stepped by turning on two of four pins in the stepping pattern. This occurs every n clock cycles, although when speed stepping is enabled, Timer2 may interrupt but not change steps, to approximate the low speed operation. Once Timer2 determines that it has turned the motor enough (based on preset variables), it disables itself. At this point, the PIC again waits for an INT interrupt.

There are several important variables that can be used to modify the operation of the PIC:

AmtPerPress – this variable is set with the number of half-rotations the motor should complete for each dispense

NumButtonPresses – indicates the number of dispenses that are allowed. More than five dispenses are allowed, although the PIC will only show five available dispenses

RampRatio – the amount of toilet paper dispensed at normal speed divided by the amount dispensed at low speed. This is used for accelerating and decelerating the motor at the beginning and end of dispensing

RampSpeed – The normal speed divided by the low speed. Note that using 1 for RampSpeed essentially disables speed ramping. Also, the total amount dispensed is independent of and ramping activity.

StepperWInt code

```
/*This program toggles PORTC pins 1-4 in a step pattern for a Portescap 26M series
stepper motor.
  Verify the step pattern before using it with a different motor.  PORTC pin 0 is turned on
when the motor
  is stepping as well to indicate it is operating.  Timer2 interrupts are used to step the
motor, and INT
  interrupts are used to pick up button presses.   */
#include        <pic.h>
//global variables
/*
int step1 = 0b10011;
int step2 = 0b11001;
int step3 = 0b01101;
int step4 = 0b00111;
*/
int step4 = 0b10101;
int step3 = 0b10011;
int step2 = 0b01011;
int step1 = 0b01101;
unsigned int i = 0;
unsigned int j = 0;
unsigned int k = 0;
unsigned int NumRemaining;
unsigned int AmtPerPress = 20;
unsigned int RampUp;
unsigned int RampDown;
unsigned int NumButtonPresses = 5;
unsigned int TotalAmount;
unsigned int RampRatio = 2; // The length of TP dispensed at normal speed is
                                                    // RampRatio times the amount
dispensed at low speed
unsigned int RampSpeed = 1; //The normal speed is RampSpeed times the low speed
/*Note: the actual total amount dispensed = ((((AmountPerPress-
RampDown)+RampUp)*1/3)/AmountPerPress + (RampDown-
RampUp)/AmountPerPress)*TotalAmount
        This is because during ramp up and ramp down it is dispensing 1/3 of regular
amount (Assuming RampSpeed = 3)
        In this case with ramp up and ramp down taking 2/5 of the time, at 1/3 speed, it
dispenses 11/15 of the total amount
*/


void interrupt IntServe(void) @ 0x10
{
```

```
if(TMR2IF)
{
	if(j<AmtPerPress){
		if(i==0){
			PORTC = step1;
		}
		if(i==1){
			PORTC = step2;
		}
		if(i==2){
			PORTC = step3;
		}
		if(i==3){
			PORTC = step4;
		}
		j++;
		if(j<RampUp)
		{
			if(j%RampSpeed==0)
			{
				i=(i+1)%4;
			}
		}else if(j>RampDown)
		{
			if(j%RampSpeed==0)
			{
				i=(i+1)%4;
			}
		}else
		{
			i=(i+1)%4;
		}
	}else{
		PORTC = 0;
		RB6 = 0;
		NumRemaining = NumButtonPresses - k;
		switch(NumRemaining)
		{
			case 4:
				RB5 = 0;
				break;
			case 3:
				RB4 = 0;
				break;
			case 2:
				RB3 = 0;
```

```
					break;
				case 1:
					RB2 = 0;
					break;
				case 0:
					RB1 = 0;
					break;
			}
			TMR2IE = 0;
		}
		TMR2IF = 0;
	}
	if(INTF==1)
	{
		if(TMR2IE==0)
		{
			k++;
			if(k<=NumButtonPresses)
			{
				TMR2IE = 1;
				j = 0;
				RB6 = 1;
			}else{
				TMR2IE = 0;
				GIE = 0;
			}
		}
		INTF = 0;
	}
}

void main(void)
{
	TRISA = 0;
	TRISB = 0x01;
	TRISC = 0;
	ADCON1 = 6;
	PORTC = 0;
	TRISB0 = 1; //RB0 input for INT

	//Set up PortB to show how many dispenses remain
	RB1 = RB2 = RB3 = RB4 = RB5 = 1;
	switch(NumButtonPresses)
	{
		case 4:
			RB5 = 0;
```

```
                break;
            case 3:
                RB5 = RB4 = 0;
                break;
            case 2:
                RB5 = RB4 = RB3 = 0;
                break;
            case 1:
                RB5 = RB4 = RB3 = RB2 = 0;
                break;
            case 0:
                RB5 = RB4 = RB3 = RB2 = RB1 = 0;
                break;
        }




        //Initialize Timer2
        T2CON = 0b01111110;
        PR2 = 100;
        TMR2IE = 0; //Turn off initially
        PEIE = 1;
        TMR2IF = 0;

        INTEDG = 0;
        INTE = 1;
        INTF = 0;

        //Calculate ramp up and ramp down
        AmtPerPress = AmtPerPress*24;
        RampUp = (int)(.5*AmtPerPress*RampSpeed/(RampRatio+1));
        AmtPerPress = 2*RampUp + AmtPerPress*RampRatio/(RampRatio+1);
        RampDown = AmtPerPress-RampUp;
        TotalAmount = AmtPerPress*NumButtonPresses;



        GIE = 1; //enable interrupts
        while(1); //wait for interrupts
}
```

Technician's Troubleshooting Information

Technician's Troubleshooting

Checking Connections and Testing Electrical Components

1. Open stall door to disable power source.
2. Open lock with designated key.
3. Open the enclosure entirely so that the printed circuit board (PCB) is exposed.
4. Check all header pins on the PCB. If any of the pins are disconnected, dismount the PCBs and re-solder and/or hot glue the connections back in place. Also, make sure all wires are connected to their header pins and hot glued in place.
5. Check to make sure both voltage regulators (the 8-pin chips on the bottom left and top middle of the main PCB) are working properly. To do this, measure the input voltage at pin 3 or 4. This voltage should read between 5V and 9V. If it is below 5V, the batteries are low (see "Replacing low batteries" section).
6. If the voltage is above 5V, measure the output voltage at pin 5, 6, or 7. The voltage regulators should be regulating the voltage output between 4.9 and 5.1 volts. If this is not the case, get the part number to replace the faulty voltage regulator and retest the circuit.
7. If both voltage regulators are supplying 5V to the rest of the circuit and all connections are good, the only other components that may not be working properly are the PIC (28-pin programmable integrated circuit) or the capacitance transducer (other 8-pin DIP).
8. If the TOUCH LED does not turn on when a hand is waved within 1 inch of the metal plate on front of the enclosure, the capacitance transducer may need to be replaced.
9. If all connections are good and all other chips are functioning properly, the PIC may need to be replaced. If it does, it must be reprogrammed. Contact personnel at the NDSU Electrical Engineering Department for help.

Replacing low batteries

1. Open stall door to disable power source.
2. Open lock with designated key.
3. Disconnect wire connector of battery pack from printed circuit board (PCB) connector.
4. Pull battery pack out of enclosure.
5. Replace old batteries with six D-cell batteries.
6. Put battery pack back into enclosure.
7. Reconnect wire connector to PCB connector.

Most likely problems to occur

If motor is spinning but not spinning freely, or if motor is not spinning at all

1. Open lock with designated key.
2. Open the enclosure entirely so that the pinch rollers are exposed.
3. Shut the stall door to enable the power source and wave hand within 1 inch of the front metal plate (sensing electrode). Check to see if the motor spins freely. If it does, it is a mechanical problem with the pinch rollers; move on to next step. If it does not, it is an electrical problem, See section labeled "Checking Connections and Testing Electrical Components."
4. Check to see if both pinch rollers spin freely. If they do not, the pinch roller mounts may not be aligned properly. Bend mounting brackets to re-align pinch rollers. If this does not help, go to next step.
5. Shut the enclosure and check to see if the pinch rollers align evenly and that the enclosure is not shut too tight. If the enclosure is putting too much pressure on the pinch rollers, the motor will not spin freely. Step 3 and 4 are the only methods of solving this problem.

If toilet paper is jammed or stuck on a pinch roller

1. This is a mechanical problem of the pinch rollers being too tight or the toilet paper getting caught on the chute on the bottom of the enclosure. Open lock of enclosure with designated key.
2. Open the enclosure entirely so that the pinch rollers and toilet paper chute are exposed.
3. Make necessary changes to pinch rollers or toilet paper chute so that is problem does not occur again.
4. Feed the toilet paper down the toilet paper chute and retest the dispenser.
5. Once the problem is solved, shut and lock the enclosure.

If no light emitting diodes (LEDs) turn on

1. Make sure the stall door is shut tightly and both ends of the door sensor are within 4 millimeters.
2. See section labeled "Checking Connections and Testing Electrical Components" to make sure circuit is connected properly. 9 volts of power should be running through the door sensor. If the circuit is not being supplied with power, the reed switch on the door may need to be replaced.

If TOUCH LED is the only LED that turns on

1. The capacitance transducer is working but the PIC is not. See section labeled "Checking Connections and Testing Electrical Components" and replace the PIC if necessary.

Project Comments

Difficulties and Lessons Learned

Throughout the course of the project, we encountered a number of challenges, some of which we were able to overcome without much difficulty, and some which we are still grappling with. For example, our budget seems relatively large, at close to 750 dollars. However, our project required making four dispensers; one prototype and three final versions. Because of this, cost was a major issue for us. Four dispensers meant that eight PCBs were needed. Since we had a limited budget, we built all eight PCBs in-house. This saved us a good deal of money, but it took a great deal of time to make, assemble, and test all eight PCBs. We also needed four enclosures for our dispensers. We did not have the money to have all the enclosures professionally built the way we originally planned, but we were able to have three of them made by Standard Industries for a reasonable price. It was time consuming and difficult to build our prototype though, as well as to find a company that we could afford to make our enclosures. Making only one dispenser initially would have saved us a good deal of money and time, but our requirements capture stated that we needed three.

While making our PCBs, we encountered some problems with the PIC resetting, LEDs turning off and voltage regulators burning up. We had a problem with this on some PCBs, but not others, and had a lot of difficulty debugging the problem. In the end, it turned out that we were using a polarized capacitor with our voltage regulator, and we accidentally installed the capacitor backwards on some of the PCBs.

Another problem we ran into numerous times throughout the project was voltage drift causing issues with our capacitive transducer. When we ran our motor, especially during transitions from one speed to another, there was enough current draw that, even when we were using the CADET board for our power supply, the power would drop enough to cause a false reading from our capacitive transducer. In consulting the data sheets for the transducer, we verified that it is very sensitive to voltage changes, and should have a dedicated supply. We redesigned our circuit to use two voltage regulators, one for the capacitive transducer and one for the rest of the circuit. We also learned that when the motor must accelerate or decelerate, it consumes significantly more project. We realized this was contributing to the false readings on the capacitive transducer. Because the circuit consumed significantly less power when the motor ran at a steady, faster speed, and the speed changes were causing spikes in the power, we chose to turn off the speed stepping in our PIC code.

One of the problems we ran into near the end of our project was with the toilet paper being dispensed out of the enclosure. We knew from the beginning that we had to strike a balance between the toilet paper being able to exit the enclosure freely, and preventing the user from pulling additional toilet paper out or inadvertently tearing the toilet paper off too high into the enclosure. When we actually built the enclosure and tested our chute, though, we still had issues despite designing to avoid them. In the end, smoother

material the chute, a piece of material to block the TP, forcing it to be torn outside the chute, and careful angling of the chute turned out to be the remedies for this problem.

Future Work

While the device is functional at its current state, a few modifications and improvements could be made to provide enhanced usability.

Currently, the amount of toilet paper dispensed and the number of dispenses is hard-coded in the software program. Having a potentiometer or other interface to allow manual adjusting of these values would be desirable.

Since part of the pinch roller is on the lid of the enclosure, pressure on the lid can cause failures. If, for example, someone placed a heavy textbook on the lid, the increased weight would cause increased roller pressure. This increased pressure could result in insufficient motor torque to turn the roller. Mounting the rollers separate from the lid and having a latching mechanism so toilet paper can be fed through could prevent this problem.

Although the estimated battery life is quite long, it could be improved through a number of power-saving features. The PIC currently checks for senses from the capacitive transducer at regularly scheduled times. Power could be conserved by scanning for touches less often and entering a low-power sleep mode when not scanning for touches. It is likely that a user will not be able to wave their hand in front of the transducer for less than 0.2 seconds, so scanning could be done.

Another possible power saving feature is a sleep mode. If the stall door is left open overnight, the device will remain powered even though the stall is not in use. One possible solution to this problem is having the PIC enter a sleep mode. Typically, nobody stays in a bathroom for more than an hour. Having the PIC enter a sleep mode, or having the PIC signal the voltage regulator to enter a sleep mode would provide significantly less power consumption.

Additionally, if the device were to go into full-scale production different oscillators could be investigated. The PIC offers an internal RC oscillator, which could decrease overall system cost by eliminating the need for a crystal oscillator. It is likely that the decreased accuracy of the clock signal introduced by using the RC oscillator would not result in degraded performance because the system is not time sensitive.